in English, a French abstract has been prepared by Prof. Dewalque, the Secretary of the General Committee on Unification of Nomenclature; and copies of this abstract will be distributed at the meeting. The English Committee, under the presidency of Prof. T. McK. Hughes, will also present its revised Report, which is now being printed, and forms a substantial work.

Opportunity will be given on Tuesday afternoon for visiting the British Museum, where the fine collections illustrative of prehistoric archæology will be examined under the guidance of Mr. A. W. Franks.

On Wednesday morning the sitting will be occupied with the discussion of a subject which has of late years been warmly debated in geological circles—the nature and origin of the crystalline schists. Special authorities on this subject have been invited to contribute short memoirs which have been printed in advance. As copies of these papers will be distributed to the members, the communications may be taken as read and the time of the meeting occupied only in their discussion. The volumes of papers entitled "Études sur les Schistes Crystallins," contains the following communications:—"Les Schistes Cristallins," by Dr. Sterry Hunt; "Zur Klassification der krystallinischen Schiefer," by Prof. A. Heim, of Zürich; "Sur la Constitution et la Structure des Massifs de Schistes Cristallins des Alpes Occidentales," by Prof. C. Lory, of Grenoble; "Bemerkungen zu einigen neueren Arbeiten über krystallinisch-schiefrige Gesteine," by Prof. J. Lehmann, of Kiel; "Sur l'Origine des Terrains Cristallins Primitifs," by M. Michel-Lévy, of Paris; "The Archæan Geology of the Region North-West of Lake Superior," by A. C. Lawson, of the Geological Survey of Canada; "On the Crystalline Schists of the United States and their Relations," by various members of the United States Geological Survey; and a paper by M. K. A. Lossen, of the Geological Survey of Prussia. The group of papers contributed by the United States Survey contains first an "Introduction," by Major J. W. Powell, the Director, followed by a paper on "The Crystalline Schists of the Lake Superior District," by the late R. D. Irving, and T. Chamberlin and C. R. Van Hise; this is succeeded by a sketch of "The Crystalline Schists of the Coast Ranges of California," by G. F. Becker, and a brief description of "The Crystalline Rocks of Northern California and Southern Oregon," by Captain C. E. Dutton.

Wednesday afternoon will be devoted to a visit to the Natural History Department of the British Museum where the visitors will be received by Prof. Flower, as Director of the establishment.

On Wednesday evening the Congress will be received by Dr. A. Geikie, as Director-General of the Geological Survey, at the Museum of Practical Geology in Jermyn Street. With the view of illustrating the subjects that will have been discussed at the morning sitting, it is proposed that during the evening a series of microscopic sections showing the structure of the crystalline schists shall be exhibited on the screen, by means of the lime-light, in the theatre of the Museum.

At 10 o'clock on Thursday morning the Congress will re-assemble in the University theatre, and proceed to the discussion of questions bearing upon the International Map of Europe. The Map Committee will present its Report, and exhibit specimen sheets illustrating the character of the work. In the afternoon the members will make excursions in various directions. One party will visit Windsor and Eton, where they will be entertained by the masters of Eton College; another party will visit Kew, and be received by Mr. Thiselton Dyer, as Director of the Royal Gardens; other members will go down the river to Erith and Crayford for the purpose of examining the brick-earths and gravels of the Thames valley; while others will probably visit Watford and St. Albans.

At the meeting on Friday morning the discussion on nomenclature and classification, and on the coloration of maps, will be resumed. In the evening there will be a reception at the rooms of the Geological Society at Burlington House, by Dr. W. T. Blanford, as President of the Society. An evening reception, the date of which is not yet fixed, will also be held by Prof. Prestwich, the President of the Congress. The concluding business of the Congress, mostly of a formal character, will be taken at Saturday morning's sitting.

By permission of the Council of the Zoological Society, the Society's Gardens in Regent's Park will be open free to members of the Congress, not only during the week of the meetings but (after 1 o'clock) on Sundays, September 16 and 23.

Several geological excursions have been organized for the week following the London session. One of these, which promises to be extremely popular, is to the Isle of Wight, under the direction of Messrs. W. Whitaker, J. Starkie Gardner, A. Strahan, and H. Keeping. By invitation of Sir Charles Wilson, this party will also visit the offices of the Ordnance Survey at Southampton. Another interesting excursion is to North Wales under Dr. H. Hicks, assisted by Prof. J. H. Blake for Anglesey, and by Mr. G. H. Morton for the Carboniferous Limestone of Llangollen. A third excursion is planned to East Yorkshire, under the direction of Mr. J. W. Woodall and Mr. C. Fox-Strangways, assisted by Mr. W. H. Hudleston, for some of the Oolitic series, Mr. G. H. Lamplugh for the Flamborough Chalk, and Mr. Hugh Bell, for the mines and iron-works of Middlesborough. West Yorkshire will also be visited by a party under the guidance of Mr. J. E. Marr and Mr. R H. Tiddeman. Finally, an excursion to East Anglia has been organized under Mr. F. W. Harmer (Mayor of Norwich) and Mr. Clement Reid, assisted for the older Pliocene beds of Suffolk by Dr. J. E. Taylor, of the Ipswich Museum. A guide-book containing geological descriptions of the localities about to be visited, written in French and illustrated by coloured geological maps, is in course of preparation, and will be presented to the members of the Congress. To this guide-book Mr. Topley has contributed a sketch of the geology of the various railway routes by which foreigners will reach London.

The great interest taken in the forthcoming meeting is attested by the fact that already between 500 and 600 members have been registered. The list includes nearly all the most distinguished geologists on the Continent and in America, many of whom will arrive in time to be present at the Bath meeting of the British Association during the week preceding the opening of the Congress. It is known that many of these geologists will bring with them collections of minerals, rocks, and fossils, for exhibition in the temporary Museum which will be formed in the library of the University of London, and which promises to be one of the most interesting features of the meeting. On the whole, there can be no question that the success of the forthcoming session of the Congress is abundantly assured.

MODERN VIEWS OF ELECTRICITY.[1]

PART IV.—RADIATION.

X.

HAVING now described a possible method of measuring the velocity of electric wave propagation, and therefore of at least the ratio of the two ethereal constants k and μ, by an experiment on the different parts of one enormously large and properly chosen circuit: return to the consideration of the ordinary small discharging Leyden jar or other alternating current circuit of a moderate size, it may be a few yards or a foot or an inch in diameter.

If the alternating currents are produced artificially by some form of alternating machine, their frequency is, of course, arbitrary; but if they be automatically caused by the recoil of a given Leyden jar in a given circuit, their frequency is, as we have already said,

---

[1] Continued from p. 393.

$$\frac{1}{2\pi\sqrt{(LS)}} \text{ per second ;}$$

where L is the electrical inertia or self-induction of the circuit, and where S is the capacity or reciprocal of the elasticity constant of the jar.

It is not convenient here to go into the determination of the quantity L, but roughly one may say that for an ordinary open single-loop circuit it is a quantity somewhat comparable with twelve or fifteen times its circumference multiplied by the constant μ.

The value of S has to do with the area and thickness of the condenser, being, as is well known, $\frac{A}{4\pi z}$ multiplied by the constant K.

The product LS contains therefore two factors, each of linear dimensions, expressing the sizes of circuit and jar, and likewise contains a factor μK expressing the properties of the surrounding medium. Hence, so far as the ether is concerned, the above expression for frequency of vibration demands only a knowledge of the *product* of its two constants K and μ, and since this is known by the previous velocity experiment, it is easy to calculate the rate of oscillation of any given condenser discharge. It is also easy to calculate the wave-length; for if there are n waves produced per second, and each travels with the velocity v, the length of each wave is $\frac{v}{n}$.

Hence the wave-length is $2\pi\sqrt{\left(\frac{L}{\mu}\cdot\frac{S}{K}\right)}$.

Now, if we go through these numerical calculations for an ordinary Leyden jar and discharger, we shall find waves something like, say, 50 or 100 yards long. They may plainly be of any length, according to the size of the jar and the size of the circuit. The bigger both these are the longer will be the waves.

A condenser of 1 microfarad capacity, discharging through a coil of self-induction 1 secohm, will give rise to ether waves 1900 kilometres or 1200 miles long.

A common pint Leyden jar discharging through a pair of tongs may start a system of ether waves each not longer than about 15 or 20 metres.

A tiny thimble-sized jar overflowing its edge may propagate waves only about 2 or 3 feet long.

The oscillations of current thus recognized as setting up waves have only a small duration, unless there is some means of maintaining them. How long they will last depends upon the conductivity of the circuit; but even in a circuit of infinite conductivity they must die out if left to themselves, from the mere fact that they dissipate their energy by radiation. One may get 100 or 1000, or perhaps even 100,000, perceptible oscillations of gradually decreasing amplitude, but the rate of oscillation is so great that their whole duration may still be an extremely small fraction of a second. For instance, to produce ether waves a metre in length requires 300,000,000 oscillations per second.

To keep up continuous radiation naturally requires a supply of energy, and unless it is so supplied the radiation rapidly ceases. Commercial alternating machines are artificial and cumbrous contrivances for maintaining electrical vibrations in circuits of finite resistance, and in despite of loss by radiation.

In most commercial circuits the loss by radiation is probably so small a fraction of the whole dissipation of energy as to be practically negligible; but one is, of course, not limited to the consideration of commercial circuits or to alternating machines as at present invented and used. It may be possible to devise some less direct method—some chemical method, perhaps—for supplying energy to an oscillating circuit, and so converting what would be a mere discharge or flash into a continuous source of radiation.

So far we have only considered ordinary practicable electrical circuits, and have found their waves in all cases pretty long, but getting distinctly shorter the smaller we take the circuit. Continue the process of reduction in size further, and ask what sized circuit will give waves 6000 tenth-metres (three-fifths of a *micron*, or 25 millionths of an inch) long. We have only to put $2\pi\sqrt{\left(\frac{L}{\mu}\cdot\frac{S}{K}\right)} =$ 0·00006, and we find that the necessary circuit must have a self-induction in electro-magnetic units, and a capacity in electrostatic units, such that their geometric mean is 10^{-5} centimetre (one-tenth of a micron). This gives us at once something of atomic dimensions for the circuit, and suggests immediately that those short ethereal waves which are able to affect the retina, and which we are accustomed to call "light," may be really excited by electrical oscillations or surgings in circuits of atomic dimensions.

If after the vibrations are once excited there is no source of energy competent to maintain them, the light production will soon cease, and we shall have merely the temporary phenomenon of phosphorescence; but if there is an available supply of suitable energy, the electrical vibrations may continue, and the radiation may become no longer an evanescent brightness, but a steady and permanent glow.

Velocity of Electrical Radiation compared with Velocity of Light.

We have thus imagined the now well-known Maxwellian theory of light, viz. that it is produced by electrical vibrations, and that its waves are electrical waves.

But what justification is there for such an hypothesis beyond the mere fact which we have here insisted on, viz. that waves in all respects like light-waves except size, *i.e.* transverse vibrations travelling at a certain pace through ether, can certainly be produced temporarily in practicable circuits by familiar and very simple means, and *could* be produced of exactly the length proper to any given kind of light if only it were feasible to deal with circuits ultra-microscopic in size? The simplest point to consider is: Does light travel at the same speed as the electrical disturbances we have been considering? We described one method of measuring how fast electrical radiation travels in free space, and there are many other methods: the result was 300,000 kilometres per second.

Methods of measuring the velocity of light have long been known, and the result of those measurements in free space or air is likewise 300,000 kilometres a second. The two velocities agree in free space. Hence surely light and electrical radiation are identical.

But there is a further test. The speed of electrical radiation was not the same in all media: it depended on the electrical elasticity and the ethereal density of the transparent substance; in other words, it was equal to the reciprocal of the geometric mean of its specific inductive capacity and its magnetic permeability—

$$v = \frac{1}{\sqrt{(K\mu)}}.$$

Now, although the absolute value of neither K nor μ is known, yet their values relatively to air are often measured and are known for most substances.

Also, it is easy to compare the pace at which light goes through any substance with its velocity in free space: the operation is called finding the refractive index of a substance. The refractive index means, in fact, simply the ratio of the velocity of light in space to its velocity in the given substance. The reciprocal of the index of refraction is therefore the relative velocity of light. Calling the index of refraction n, therefore, we ought, if the electrical theory of light be true, to find that $n^2 = K\mu$; or that the index of refraction of any substance is the geometric mean of its electrostatic and magnetic specific capacities.

That this is precisely true for all substances cannot at present be asserted. There are some substances for which it is very satisfactorily true: there are others which are apparent exceptions. It remains to examine whether they are not only apparent but real exceptions, and, if so, to what their exceptional behaviour is due.

It must be understood what the essential point is. It has been proved by various methods, and with greater approach to exactness as the accuracy of the methods is improved, that electrical disturbances—such as the long waves emitted by any alternating machine—travel through air or free space with exactly the same velocity as light; in other words, that there is no recognizable difference in speed between waves several hundred miles long and waves so small that a hundred thousand of them can lie in an inch. This is true in free ether, and it is a remarkable fact. If it proves anything concerning the structure of the ether, it proves that it is continuous, homogeneous, and simple beyond any other substance; or at least that if it does possess any structural heterogeneity, the parts of which it is composed are so nearly infinitesimal that a hundred miles and the hundred-thousandth of an inch are quantities of practically the same order of magnitude so far as they are concerned: its parts are able to treat all this variety of wave-length in the same manner.

But directly one gets to deal with ordinary gross matter we know that this is certainly not the case. Ordinary matter is composed of molecules which, though small, are far from being infinitesimal. Atoms are much smaller than light-waves, indeed, but not incomparably smaller. Hence it is natural to suppose that the ether as modified by matter will be modified in a similarly heterogeneous manner; and will accordingly not be able to treat waves of all sizes in the same way.

The speed of all waves is retarded by entering gross matter, but we should expect the smallest waves to be retarded most. The phenomenon is well marked even within the range of such light-waves as can affect the retina: the smaller waves—those which produce the sensation of blue—are more retarded, and travel a little slower, through, say, glass or water, than the somewhat larger ones which produce the sensation of red. This phenomenon has long been known, and is called dispersion. Hence it is not easy to say at what rate waves a few inches or a few yards or miles long ought to travel, by merely knowing at what rate the ultra-microscopic light-waves travel.

But there is even more to be said than this. There is not only dispersion, there is selective absorption possessed by matter: not only does it transmit different-sized waves at different rates, but it absorbs and quenches some much faster than others. Few substances, perhaps none, are equally transparent to all sizes of waves. Glass, for instance, which transmits readily the assortment of waves able to affect the retina, is practically quite opaque to waves a few hundred times longer or shorter. And whenever this selective absorption occurs, the laws of dispersion are extraordinary—so extraordinary that the dispersion is often spoken of as "anomalous"; which of course means, not that it is lawless, but that its laws are unknown. Dispersion in any case is an obscure and little understood subject, but dispersion modified by selective absorption is still worse. Until the theory of dispersion is better understood, no one is able to say at what speed waves of any given length ought to travel. One can only examine experimentally at what rate they *do* travel. This has been done for long electrical waves, and it has been done for short light-waves: in the case of some substances the speed is the same, in the case of others it is different. But that the speed should be different is, as I have now explained, very natural, and can by no means be twisted into an admission that light-waves and electrical waves are not essentially identical. That the speed of both should agree at all is noteworthy; the agreement appears to be exact in air, and practically exact in such simple substances as sulphur, and in the class of hydrocarbons known as paraffins; whereas in artificial substances like glass, and in organic substances like fats and oils, the agreement is less perfect.

So much for the vital question of the speed at which electrical and optical disturbances travel. In some cases the speeds are accurately the same, in no case are they entirely different; and in those cases where the agreement is only rough, an efficient and satisfactory explanation of the difference is to hand in the very different lengths of wave which have at present been submitted to experiment. To compare the speeds properly, we must either learn to shorten electrical waves, or to lengthen light-waves, or both, and then compare the two things together when of the same size.

It cannot be seriously doubted that they will turn out identical.

Manufacture of Light.

The conclusions at which we have arrived, that light is an electrical disturbance, and that light-waves are excited by electric oscillations, must ultimately, and may shortly, have a practical import.

Our present systems of making light artificially are wasteful and ineffective. We want a certain range of oscillation, between 7000 and 4000 billion vibrations per second: no other is useful to us, because no other has any effect on our retina; but we do not know how to produce vibrations of this rate. We can produce a definite vibration of one or two hundred or thousand per second, in other words, we can excite a pure tone of definite pitch; and we can command any desired range of such tones continuously by means of bellows and a keyboard. We can also (though the fact is less well known) excite momentarily definite ethereal vibrations of some million per second, as I have at length explained; but we do not at present seem to know how to maintain this rate quite continuously. To get much faster rates of vibration than this we have to fall back upon atoms. We know how to make atoms vibrate: it is done by what we call "heating" the substance, and if we could deal with individual atoms unhampered by others, it is possible that we might get a pure and simple mode of vibration from them. It is possible, but unlikely; for atoms, even when isolated, have a multitude of modes of vibration special to themselves, of which only a few are of practical use to us, and we do not know how to excite some without also the others. However, we do not at present even deal with individual atoms; we treat them crowded together in a compact mass, so that their modes of vibration are really infinite.

We take a lump of matter, say a carbon filament or a piece of quick-lime, and by raising its temperature we impress upon its atoms higher and higher modes of vibration, not transmuting the lower into the higher but superposing the higher upon the lower, until at length we get such rates of vibration as our retina is constructed for, and we are satisfied. But how wasteful and indirect and empirical is the process. We want a small range of rapid vibrations, and we know no better than to make the whole series leading up to them. It is as though, in order to sound some little shrill octave of pipes in an organ, we were obliged to depress every key and every pedal, and to blow a young hurricane.

I have purposely selected as examples the more perfect methods of obtaining artificial light, wherein the waste radiation is only useless, and not noxious. But the old-fashioned plan was cruder even than this, it consisted simply in setting something burning: whereby not only the fuel but the air was consumed, whereby also a most powerful radiation was produced, in the waste waves of which we were content to sit stewing, for the sake of the minute, almost infinitesimal, fraction of it which enabled us to see.

Everyone knows now, however, that combustion is not a pleasant or healthy mode of obtaining light; but everybody does not realize that neither is incandescence a satisfactory and unwasteful method which is likely to be practised for more than a few decades, or perhaps a century.

Look at the furnaces and boilers of a great steam-engine driving a group of dynamos, and estimate the energy expended; and then look at the incandescent filaments of the lamps excited by them, and estimate how much of their radiated energy is of real service to the eye. It will be as the energy of a pitch-pipe to an entire orchestra.

It is not too much to say that a boy turning a handle could, if his energy were properly directed, produce quite as much real light as is produced by all this mass of mechanism and consumption of material.

There might, perhaps, be something contrary to the laws of Nature in thus hoping to get and utilize some specific kind of radiation without the rest, but Lord Rayleigh has shown in a short communication to the British Association at York[1] that it is not so, and that therefore we have a right to try to do it.

We do not yet know how, it is true, but it is one of the things we have got to learn.

Anyone looking at a common glow-worm must be struck with the fact that not by ordinary combustion, nor yet on the steam-engine and dynamo principle, is that easy light produced. Very little waste radiation is there from phosphorescent things in general. Light of the kind able to affect the retina is directly emitted, and for this, for even a large supply of this, a modicum of energy suffices.

Solar radiation consists of waves of all sizes, it is true; but then solar radiation has innumerable things to do besides making things visible. The whole of its energy is useful. In artificial lighting nothing but light is desired; when heat is wanted it is best obtained separately, by combustion. And so soon as we clearly recognize that light is an electrical vibration, so soon shall we begin to beat about for some mode of exciting and maintaining an electrical vibration of any required degree of rapidity. When this has been accomplished, the problem of artificial lighting will have been solved. OLIVER J. LODGE.

(*To be continued.*)

STORM WARNINGS.

TWENTY-EIGHT years ago, M. Le Verrier wrote to the Astronomer-Royal at Greenwich inviting the co-operation of this country in his scheme for giving warning of storms by announcing them and following their course by telegraph as soon as they appear at any point of Europe, and in the following year (1861) Admiral FitzRoy established his system, giving notice of storms before they actually strike our coast. Notwithstanding the success which has attended these efforts, storms sometimes overtake us before warning of their approach can be given, and every endeavour to increase our foreknowledge of their movements should be gladly welcomed. Since the year 1860 much additional light has been thrown upon the subject by the systematic publication of synchronous charts, such as those commenced by the late Captain Hoffmeyer, Director of the Danish Meteorological Institute. Several attempts have also been made to utilize the Atlantic cables with the object of giving warning of storms leaving the American coast or met with by the fast steamers bound to the United States; but these efforts have hitherto met with little success from want of sufficient knowledge of the conditions existing over the Atlantic, many storms passing wide of the British Isles, others originating in mid-ocean or dying out there. Of the endeavours to connect our knowledge of the weather over the Atlantic with the reports received from the two shores, the labours of Captain Hoffmeyer as explained in "Études sur les Tempêtes de l'Atlantique septentrional" (Copenhagen, 1880), and recent publications of M. Léon Teisserenc de Bort in the *Annales* of the Central Meteorological Office of France, deserve especial attention. With the view of utilizing the American weather reports for the purpose of improving European weather predictions, M. de Bort has made an investigation of the mean positions of high and low pressures in the northern hemisphere for all winters since 1838, and he shows how these great centres of atmospheric action correspond to different types of weather, that during each season these centres are limited in number, and that each of them when displaced still lies within a definite area.

During the winter season, for instance, the maxima are arranged as follows:—(1) The maximum of Asia, which generally includes two parts, one being near Irkutsk, the other either in Siberia or Russia, one of the positions being usually to the south-west of Tobolsk. (2) The maximum of Madeira, which is also sometimes split up into two parts, one being over the ocean and the other over Switzerland and Central Europe, or joining with a part of the high pressures of Asia. (3) The Bermuda maximum, which is often found over the east of the United States or even in the neighbourhood of Nova Scotia. (4) The continental maximum of America, which usually lies over the mountainous parts. (5) The Polar maximum, which appears over Greenland, Iceland, or Norway. With respect to the minima, there are (1) the low pressure situated over the north of the Atlantic, which may be called the Iceland minimum; (2) a minimum which is mostly to be found in America, generally over the region of the Great Lakes; and (3) a minimum which appears to belong to the Arctic Ocean, and whose centre generally lies near Nova Zembla. These mean positions are laid down in recent barometrical charts, such as those of the Meteorological Office and other institutions. The maxima and minima may combine respectively, but there are scarcely any conditions where at least three centres of high pressure and two centres of low pressure are not to be found between China and California, and between the equator and 80° N. latitude. When the positions of the high and low pressures are well known, we may proceed like the naturalist, and discover, by the examination of some portions, those that are wanting to the whole. The introduction of this method into meteorology has a direct application in the prediction of weather. The telegraphic reports now received allow of the construction on one hand of the isobaric chart over Europe (which ought to be extended as far as Asia), and the isobars in their general features over the United States; between the two there remains the great unknown of the Atlantic. Now by a methodical discussion of the isobars of the two shores of the ocean we ought to be able to reconstitute the conditions over the Atlantic with a great amount of probability. But how are we to know that there are not two or three centres of depression over the ocean, for the number of depressions is not limited? Evidently this is very difficult; but for the object in view—viz. to reconstruct the general features of the isobars with sufficient accuracy to make use of the data for forecasting the weather in Europe—the difficulty is not so great. In fact, either the depressions are grouped so as to be only the subsidiary disturbances of a great minimum, and in this case the position of the minimum may be indicated, which is the important point, or they are completely separated, forming distinct systems of low pressure, and then the trace of them is found in the isobars on the coasts, and often even in the

---

[1] B.A. Report, 1881, p. 526.